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Urban Transport Energy Consumption: Determinants and Strategies for its Reduction.

An analysis of the literature.

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Perspectives

Urban transport energy consumption: determinants and strategies for its reduction
An analysis of the literature

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Abstract

The following article is an analysis of urban sustainability with reference to the threat of climate change. We will be focusing on urban transport energy consumption since this is the greatest challenge and an area in which policies adopted in the near future will have a crucial impact on long term energy consumption. Based on a critical review of the literature, we will begin with a recapitulation of what is known today of urban transport energy consumption determinants (Part 1). We will be discussing the role of average density and its determinants, the influence of urban structures, defined as the spatial distribution of activities and households, and finally, the structuring effects of successively dominant transport technologies. We will then review recent forms of urban development, which are a source of concern (Part 2), and the pessimistic aspects of this finding (Part 3). We will then consider possible solutions to curb non-sustainable urban developments (Part 4). We will be pleading in favour of urban planning which explicitly integrates interaction between transport and land use. We will then be discussing the set of tools which city planners can make use of, analysing their pertinence and the possible interconnection between transport policies and land use policies capable of redirecting urban growth towards sustainable paths.

Keywords: Urban transport, transport policy, urban growth, city, infrastructure, urban planning, energy use, smart city

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In the third world, urbanisation transition is massive, extremely swift and concentrated in very large cities. Today, half of the world's population lives in urban areas. In 2030, the global urban population will number 4.9 billion people, i.e. 60% of the population. Almost all global population growth will be in the cities of the South, where population will double from two to four billion people. Taking in two billion new urban dwellers means building and providing for the equivalent each year of seven new cities of ten million inhabitants, that is seven "Shanghais" or "Jakartas", or ten "Londons" per year. In a word, massive urban growth. In countries of the South, urban population growth is five to eight times faster than in industrialised countries[1] (UN, 2007). There is no precedent in history for such rapid growth, at least not on this scale: it took one hundred and thirty years for London to grow from one to nearly eight million residents. It only took forty-five years for Bangkok, thirty-seven for Dhaka and twenty-five for Seoul to achieve the same demographic leap forward (UN-HABITAT, 2004).

It is undeniable that such massive and rapid urbanisation raises daunting problems in at least two areas. First, such growth requires gigantic "urban settlement" investments (referring to the concept set out by Jean Marie Cour and Michel Arnaud in Cour, 2005), failing which the potential advantages of city life will not be accessible to the poorest. Then, taking into consideration the life time of urban structures, the type of urban growth which will be found in the cities of the South in the next thirty years of exceptionally rapid urbanisation will determine their energy consumption and their greenhouse gas emissions in the second half of the century. Depending on whether the cities of the South follow the model of Atlanta or of Barcelona (Barcelona houses and employs 20% more inhabitants than Atlanta, in an area 26 times smaller, and consumes 11 times less energy per inhabitant for urban transport), climate change will take on very different proportions by the end of the century.

In this article, we will analyse the second of these challenges[2]: the sustainability, in terms of the threat of climate change, of urban growth in the South. We will focus on urban transport energy consumption since this is where the most challenging problems need solving and where the policies adopted in the immediate future will have a crucial impact on long term energy consumption.

Energy consumption by urban transport is a particular reason for concern for several reasons. First of all, it already represents a large share of the urban energy balance, generally equivalent to the residential share, that is between 20% and 50% of total urban energy consumption (excluding industry). Furthermore, the trends scenarios forecast that it is this consumption that will experience the highest growth[3]. Experts agree on a current trends scenario in which urban mobility based on individual motorised modes of transport experiences a boom[4]. Finally, analysing the factors determining urban transport energy consumption is extremely complex and these factors are less easily influenced by public policies. Moreover, urban spatial structures, whose influence on the demand for transport and therefore on transport energy consumption is easy to understand, have a lifetime and a resilience far greater than those of buildings. Urgent action is required on this score and action now will condition the future for a very long time.

We shall begin with a recapitulation of what we know at present of the urban transport energy consumption determinants (Part 1). We will consider recent developments, which are a cause for concern (Part 2), then the pessimistic aspects of this finding (Part 3). We will then consider possible solutions for redirecting the course of unsustainable urban developments (Part 4).

1. THE DETERMINANTS OF URBAN TRANSPORT ENERGY CONSUMPTION

1.1. OVERVIEW: CONSIDERABLE DIVERSITY AND IMPORTANCE OF URBAN FACTORS

A study by Kenworthy (2003) of 84 "global cities" provides valuable points of comparison and shows the extreme diversity of cities today. CO_2 emissions released by urban passenger transport systems vary by a factor greater than 100, ranging between extremes of 2033 CKge per inhabitant and per year in Atlanta and 19 CKge for Ho Chi Minh City. As regards the share of public (*versus* private) transport in such emissions, it varies from over 70% in Manila or Dakar to less than 1% in Atlanta, but also in Riyadh.

Although the finding is unexpected, prosperity — measured in the annual GDP per capita — is not a factor which is highly correlated to the rate of private motorisation. Moreover, even with similar motorisation rates, actual use of cars may vary considerably from one city to another (Kenworthy, 2003). As a result, energy consumption due to private transport related to wealth, measured in MJ/$1000 of GDP, does not increase systematically with GDP per capita. The highest levels are to be found in three groups of cities: African cities with 2200 MJ/$1000 of GDP and cities in the United States and the Middle East with 1900 MJ/$1000 of GDP. High-income cities in Western Europe and Asia perform best with only 489 and 303 MJ/$1000 of GDP respectively. Other regions average 1364 MJ/$ of GDP, in between the two extremes.

As regards infrastructure, the length of urban expressway available per capita is particularly high in the United States (156 m/1000 inhabitants), Australia and New Zealand (83% of the American figure) and in Canada (78% of the American figure). In other regions, the urban expressway network is not extensive, particularly in Latin America and in China (2% of the American level). If, however, the expressway offer is related to wealth (instead of the number of inhabitants), the results are reversed: poor cities provide a little more urban expressway facilities than their high-income counterparts: 4.5 km compared to 4.1 km/$1000 of GDP. In fact, cities in Africa, Eastern Europe and the Middle East currently provide more expressway surface per $1000 of GDP than American cities.

1 The rate of urban growth is 4.1% for the least developed countries, 2.53% for developing countries and 0.53% for the most developed.
2 For an analysis of the first challenge, financing "essential services" so that the city can also serve the poor effectively, see Giraud et al. 2006.
3 CO_2 emissions due to transport increased at an annual rate of 2.4% between 1990 and 1995, that is at a rate considerably greater than those prevailing in the various sectors (industry 0.4%, agriculture 0.8%, construction 1% and waste 1% - Wright, 2004).
4 Globally, the number of cars will grow from 1 billion in 2007 to 2.6 billion in 2030. (Wright, 2004).

The public transport supply, evaluated as seats-Km per capita and per annum is on average not very different in rich and poor cities: 3336 in rich areas and 3203 in poorer areas. As related to wealth, however, poor cities supply much more public transport facilities: 831 seats-km/$1000 of GDP compared to the offer of rich cities, i.e. 126 seats-km/$1000 of GDP.

These findings highlight the impact of urban factors and the existence of alternatives to using cars on a city's transport-related energy consumption. They confirm the statement by Litman and Laube (2002), according to which: *"Many wealthier regions have balanced transportation systems while some poorer regions are quite automobile dependent. The differences result from public policies that affect transport choices and land use patterns"*.

1.2. THE ROLE OF AVERAGE URBAN DENSITY IN URBAN PASSENGER TRANSPORT-RELATED ENERGY CONSUMPTION ACCORDING TO NEWMAN AND KENWORTHY

Research in the last fifteen years by Newman and Kenworthy on automobile dependence and sustainable urban development, points out that there is a great deal of interaction between urban density and transport-related energy consumption.

Newman and Kenworthy's famous hyperbola "Urban density and transport-related energy consumption" shows a high correlation ($R2 = 0.86$) between average urban density and intra-urban transport-related energy consumption per capita. These results

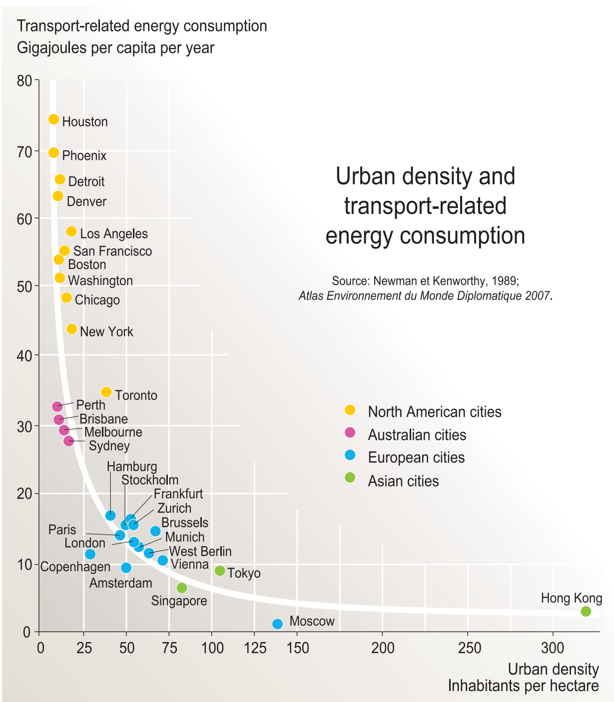

Figure 1 : The Newman and Kenworthy hyperbola: Urban density and transport-related energy consumption

are due to density being highly correlated with modal distribution and the intensity of automobile use, as shown in table 1.

Global urban density	**Low** ‹ 25 hab/ ha	**Medium** 50 – 100 hab / ha	**High** › 250 hab+/ ha
Modal distribution	MPT: 80% PT: 10% NMT: 10%	MPT: 50% PT: 25% NMT: 25%	MPT: 25% PT: 50% NMT:25 %
Automobile use (km / pers / yr)	› 10 000		‹ 5 000
Public transport use (trips / pers / an)	‹ 50		› 250
Petrol consumption for transport (MJ / pers / an)	› 55,000	35,000 – 20,000	‹ 15,000
Representative positions	North American and Australian cities	European cities	Asian cities

Table 1: City typology based on average urban density and transport. MPT: Motorised Public Transport. PT: Public Transport. NMT: Non Motorised Transport. Density: number of inhabitants and jobs per hectare of net urban surface (omitting green and water surfaces)
Source: (Newman and Kenworthy, 1999).

Low density metropolitan areas exhibit an almost total predominance of automobile use and total transport-related energy consumption is considerable (frequently more than 65,000 MJ/person/yr.). High density metropolitan areas have a markedly more balanced tri-modal distribution with a clear emphasis on public transport (from 40 to 60% of travel). The total transport-related energy consumption is four to seven times less than in low density cities. European cities occupy an intermediate position as regards urban density: between 40 and 120 (inhabitants+jobs) net per hectare. Modal distribution is more balanced but cars are still very dominant, particularly in peripheral low density suburban areas. Total transport-related energy consumption is two to four times lower than in low density cities.

While the general conclusions put forward by Newman and Kenworthy are not disputed, they have been criticised, in particular because the spatial distribution of activities and households is not analysed. The spatial structure of a city, in particular the relative location of homes, employment and amenities, also has an impact on the number and length of trips. An analysis of average density is not sufficient to explain transport-related energy consumption. The "superficial" nature of the analysis leads to the "obsession with density" described by Breheny in 1991. A. Bertaud's work seeks to respond to this type of objection.

1.3. URBAN DENSITY IS DEPENDENT ON URBAN POLICIES, NOT ON URBAN WEALTH, NOR ON THE SIZE OF URBAN POPULATION

A comparison of 49 mega-cities shows that there is no clear correlation between density and wealth, nor between density and population size (Bertaud, 2003). But a city's density depends very much on its geographic location: American cities have low densities; European, African and Latin-American cities have a

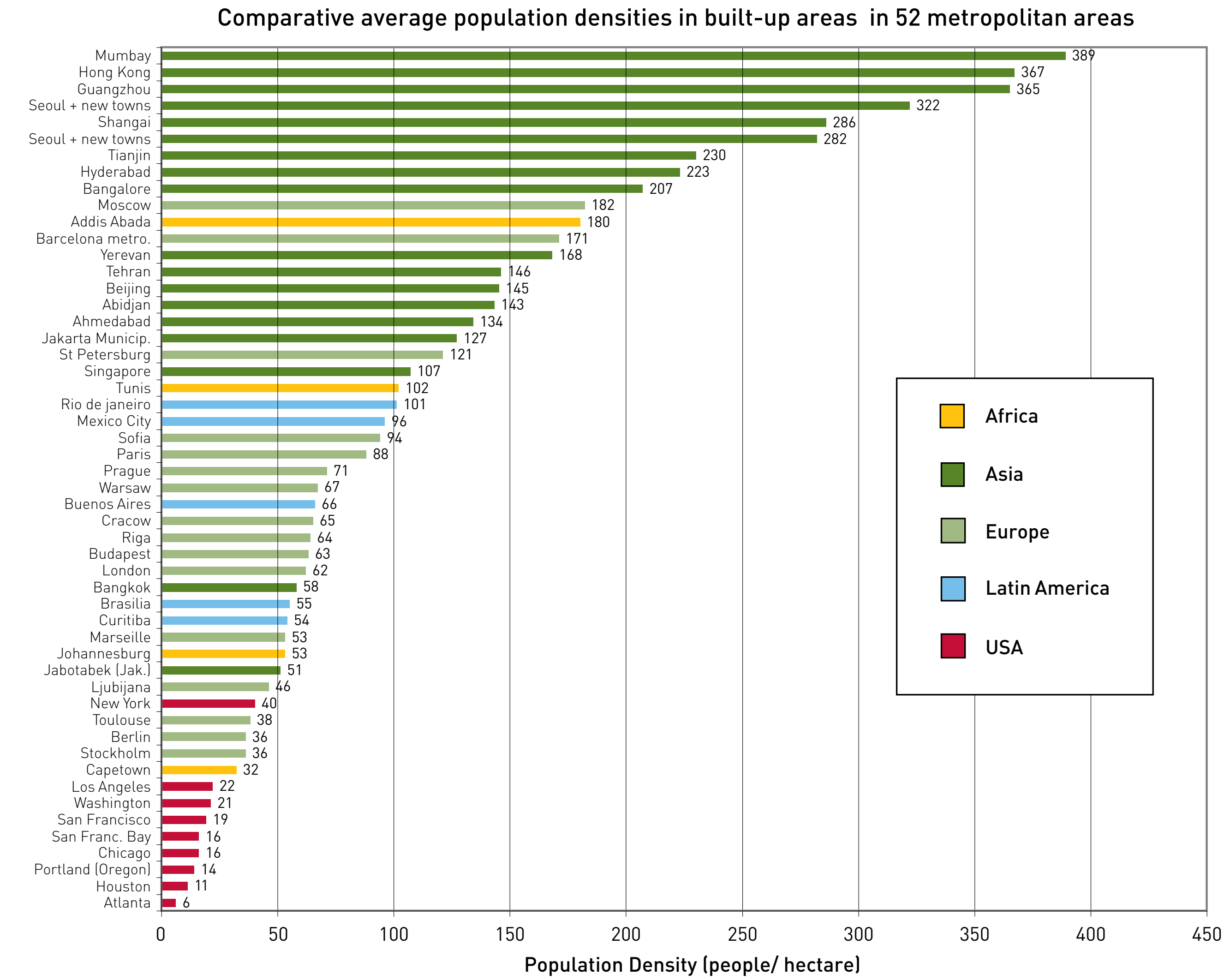

Figure 2. Comparison of average density in 49 metropolitan areas. Source: Adapted from Bertaud, 2003.

medium density; density is high in Asian cities. This suggests that density is strongly influenced by historic and cultural factors, and therefore by long term urban policies.

Moreover, as Bertaud is comparing cities which are all economic drivers in their respective countries, the broad spectrum of densities proves that in economic terms there is no such thing as "good", "adequate", "manageable" or "acceptable" density. None of the cities in this sample, representing in aggregate 250 million people (i.e. 10% of the world's urban population in 1990), should be considered as having "too high" or "too low" density with a consequent limiting effect on its economic development or its manageability.

1.4. THE ROLE OF URBAN STRUCTURE ACCORDING TO BERTAUD

Bertaud's proposed urban dynamics throws light on the role of urban forms on journeys and therefore acts as a useful complement to approaches based on average density. The author contends that the spatial distribution of population and employment densities and journeys within the urban area are much more important than average density to explain the number and the length of these journeys and the energy they consume.

Bertaud further defines urban spatial structure using two complementary components: 1) spatial distribution of the population and 2), spatial distribution of trip patterns of people when they travel between their homes and places where they either work or socialise.

1.4.1. THE SPATIAL DISTRIBUTION OF POPULATION

He gives a graphic representation of the spatial distribution of population in the form of a three-dimensional object: built-up urban area is shown on the XY plane and population densities within that area in dimension Z.

The spatial structures shown in the above figure appear to be complex and highly diversified. To gain a better understanding of the impact of these urban spatial structures on transport-related energy consumption, an analysis of the geometrical properties of these three dimensional objects is required instead of just average density. One of these properties, the density gradient, i.e. the direction and speed with which density changes as it progresses from the centre to the periphery, throws a great deal of light on the effects of regulating land and property markets on the urban space structuring process.

1.4.2. THE DENSITY GRADIENT

In the great majority of cases, the density profile is more or less aligned with the negative exponential curve predicted in the models (Alonso, 1964; Mills, 1967; Muth, 1969; Fujita and Ogawa, 1989). According to urban micro-economics, the negative gradient is generated by the economic competition between the various urban actors for a location as close as possible to the city centre.

Comparing various urban forms, Bertaud demonstrates that this negative exponential density is in fact mainly the result of the way in which the real estate market, which is always regulated to some extent, albeit with considerable variation from one country to another, actually functions. The type of land use regulation, taxation and government sponsored infrastructure all play an essential role in the way in which land and real estate markets operate. Hence, they affect urban space structuring patterns and therefore the density profile. A positive gradient is a factor for an increase in urban transport energy consumption, since for a given average density, in a city with a positive density gradient, the average distance per person to the central business district (CBD) will always be longer than for an equivalent city with a negative density gradient. It therefore seems reasonable to assume that journeys will be longer.

According to Bertaud, urban spatial structures are particularly resilient and path dependencies are strong. The density profile is so resilient that even in cities where there has been a historic interruption of the property market, as in Warsaw or Beijing, the negative gradient is retained. However, certain cities, such as Brasilia, Moscow and Johannesburg, where the market was regulated for an extended period, have positive gradients. The spatial structure of a city therefore significantly limits possible future developments.

1.4.3. THE SPATIAL DISTRIBUTION OF TRAVEL

The urban form which has most inspired economic models of urban dynamics is the monocentric city with a "Central Business District" (CDB). Pioneer work by Alonso (1964), Muth (1969) and Mills (1972) on density gradients in urban areas are therefore based on a monocentric city assumption. But with time, it became clear that many city structures do not follow the monocentric model and that trip generating activities are distributed in "clusters" throughout the urban area and outside the CBD. Bertaud identifies four cases in point to describe the travel spatial distribution of a city (Figure 4).

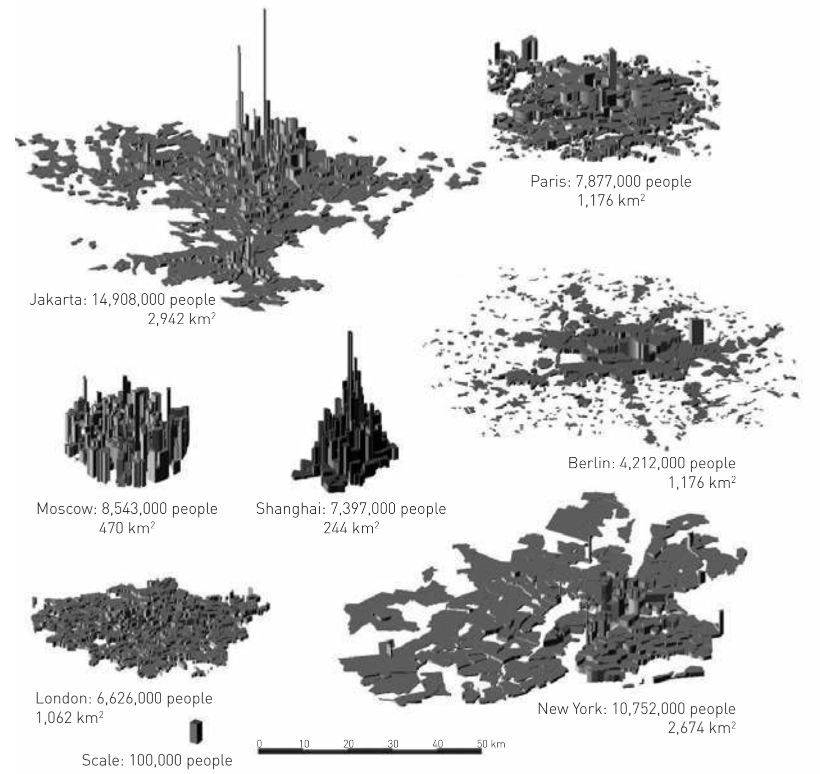

Figure 3. Residential density distribution in several cities. Source: (Bertaud, 2001).

The monocentric city. The labour market can remain unified since commuting from the suburbs to the centre is easily achieved along radial roads or using rail transport. (Figure 4a). If land and real estate markets are almost or entirely free of regulation, density tends to follow the price of land and the density gradient has a negative slope from the centre to the periphery (London and New York in Figure 3 and, curiously enough, also Shanghai, which is an illustration of the fact that, in the absence of a market, the same result can be obtained through planning…).

The polycentric city, the "urban village" type (Figure 4b). Some urban planners see this model as a kind of ideal with communities emerging around an employment cluster. These self-supporting "urban villages" will aggregate to form a sprawling polycentric city with a sometimes fairly low average density. Despite the sprawl, in such cities, trips are extremely short. Ideally, everyone can walk or cycle to work. According to Bertaud, these ideal conditions have never, alas, been observed in any city. They add up to an extreme fragmentation of the labour market. This "self-supporting urban villages" vision is therefore a contradiction of what is for many people the raison d'être of mega-cities: economy of scale obtained through a large and integrated labour market.

And yet this Utopian vision is persistent in the minds of many urban planners. Stockholm, Seoul and Shanghai have supplied some interesting examples over the last 20 years: while housing construction is directly linked to satellite towns and the existence of local employment, in fact most of those living in these satellites commute to work in the city itself and city dwellers occupy the jobs available in the satellite towns. The result is a third type of city: the polycentric city with quasi "Brownian" type movements (Figure 4c).

The fourth type of city is the result of a development in initially monocentric large cities whose structures have gradually evolved into a polycentric pattern. The CBD loses its primacy and activity clusters generating journeys are distributed throughout the built-up urban area (Figure 4c). Mega-cities were not born polycentric, they gradually evolved to that formation (Cf. Jakarta, Figure 3, where emerging polycentricism is very noticeable). Certain circumstances tend to accelerate this mutation towards polycentricity: a historical centre with few amenities, a high rate of motorisation, low cost of land, flat topography, a grid-like street network. Other factors would tend to curb such mutation: a historical centre with good amenities, rail-based public transport, an originally radial-type street network and topography unfavourable to easy communication between suburbs.

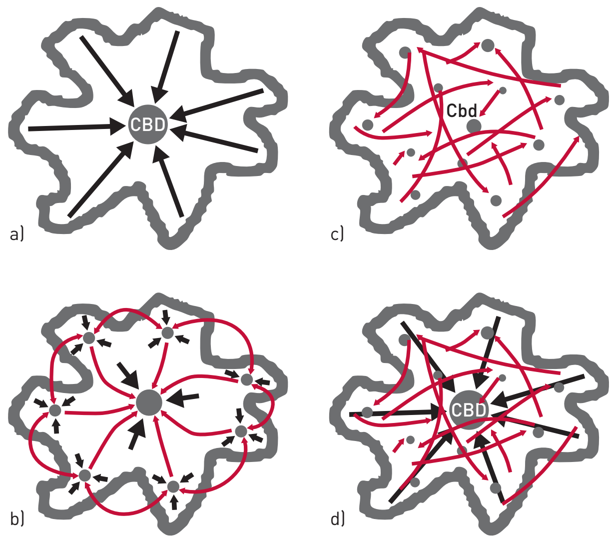

Figure 4. Typologie of urban movement according to Bertaud.
a) The monocentric model
b) The polycentric model: The urban village version
c) The polycentric model: The random movement version
d) The mono-polycentric model: Simultaneous radial and random movements
Legend:Schematic representation of trip patterns within a metropolitan area according to Bertaud. Strong Links (Black arrows) and weak links (Red arrows). Source: (Bertaud, 2001).

In a polycentric city, each secondary centre generates travel from the whole urban area. Points of origin and destination are highly scattered for these trips; they are almost random. They tend therefore to be longer than in a monocentric city, all else being equal. Bertaud considers that it is also to be expected that polycentric cities have a negative slope density gradient centred on the "centre of gravity" of the urban area, which may or may not be the CBD. But the slope cannot be as steep as for a monocentric city, since proximity to the centre of gravity provides less accessibility to the entire set of destinations than is the case in a monocentric city. These theories are verified in cities such as Los Angeles and Atlanta

1.4.4. LINKS BETWEEN URBAN STRUCTURE AND EFFICIENCY OF VARIOUS TRANSPORT MODES.

Public transport is incompatible with low density and dominantly polycentric urban structures. Bus stops and railway stations must be easily accessible from homes or workplaces and walking speeds do not exceed 4.5 km/hr. Acceptable walking distances vary with cultures and incomes, but various surveys have shown that city dwellers prefer to avoid walking for more than 10 minutes. As a result, public transport stops have an 800 metre catchment area, which can be extended using feeder systems, generally minibuses or collective taxis. But this kind of arrangement gives rise to classic inter-modal problems: lost time, increases in direct costs if the system is not price-integrated, need for specific commuting infrastructure so that necessary investment costs are increased.

Be that as it may, as such, investment in public transport infrastructure is only economically justifiable if housing and employment density is sufficient within the catchment area of the stops. As a result, a consensus is emerging between researchers and urban planners on a density pertinence threshold for public transport of approximately 30 inhabitants/ha. Bertaud (2003) draws the conclusion that there are effectiveness areas for each type of transport at the crossover point between densities and the degree of mono/polycentricity.

Bertaud's approach helps to define — in very general terms so far — what should be our objectives for cities if we are mindful of the greenhouse effect: to remain compatible with public transport, therefore stay dense and moderately polycentric, or go back to this pattern, which is certainly more difficult to achieve.

The main criticism that can be levelled at Bertaud's research is that it does not take into account the structuring interactions between transport technology and urban forms. As far as Bertaud is concerned, the latter are a particularly resilient fact to which transport technologies must, of necessity, adapt. He does not attempt to broach the systemic complexity of the "transport-urbanisation" tandem, although this is where public policies can be effective.

1.5. SUCCESSIVELY DOMINANT TRANSPORT TECHNOLOGIES DETERMINE THE EVOLUTION OF URBAN STRUCTURES AND THEREFORE OF URBAN TRANSPORT ENERGY CONSUMPTION

Considering the relationship between transport systems and urban structure from the opposite viewpoint, some authors believe that the way in which saturation of the infrastructure transport system is managed will define the urban form. This approach, opposite to the one we presented in the preceding section, is based in particular on Zahavi's double constant (1980), giving prominence to the fundamental importance of the speed of transportation modes in city spatial operation and on the correlation between average urban densities and the modal distribution of journeys (Newman, Kenworthy, 1999). From this angle, the structuring effect of transport infrastructure on the evolution of the spatial design of cities becomes apparent.

A typology of urban forms also uses this approach based on successive technological revolutions and therefore on the evolution of dominant transport modes (Schaeffer, 1975; Newman and Kenworthy, 1995; Barter, 1999).

1.5.1. THE ZAHAVI CONJECTURE

On a sample of world cities, Zahavi observed a double budget and time constant in urban mobility: on the one hand, the average time spent daily in transport is constant and equal to one hour; on the other hand, urban dwellers spend on average 11% of their budget on transport.

As a result, the daily time budget devoted to transport remains constant despite developments in the speed of travel (Zahavi, 1980).

Zahavi then conjectures that if a transport system is faster and cheaper, city dwellers will use it to travel more and to cover a greater distance, not to save time or money. If transport infrastructure permits, users prefer to broaden their range of options rather than reduce the general cost of travel.

The speed of transport systems then defines individual travel range. Since walking can cover 5 km/hr, and therefore permits a 2.5 km return journey to be covered in one hour, it gives access to a 20 km^2 range (a circle with a 2.5 km radius). Similarly, car travel being on average 10 times faster, the accessible area is a hundredfold larger, i.e. 2000 km^2.

Following Zahavi's theory, we can see that the speed of transport modes has a highly modifying effect on urban appearance. An increase in the average speed of a transport system leads to lengthening travel distance, with as a result, urban sprawl and reduced density.

1.5.2. THE WALKING CITY

As walking was the first means of transport available to mankind, the urban space in the first cities to appear in the Middle East (Bairoch, 1996) was structured accordingly. Walking speed being 5 km/hr, the area city dwellers can cover is limited. As a consequence, the surface of walking cities is restricted to a few hectares and population density is particularly high, approximately 10,000 to 20,000 inhabitants/km^2 (Newman and Hogan, 1987). Total population of these cities is also limited to little more than one million people: thus with 1.1 million citizens, Beijing was the largest city in the world in 1800 and it is thought that Rome had 1.2 million inhabitants in AD 200 (Moriconi-Ebrard, 2000). These cities have a highly varied use of space. Journeys cover short distances but are very scattered around the city (Newman, 1966).

Until the 19th century, the only other forms of land transport used animal force to draw heavy loads (carts, donkeys, horses, etc.) or to give wealthy people the advantage of greater speed and comfort using animal energy (wagons, carriages) or human energy (sedan chairs, rickshaws). Nowadays, there are practically no human settlements where travel is exclusively pedestrian.

Relationship between spatial structure and the effectiveness of public transportation

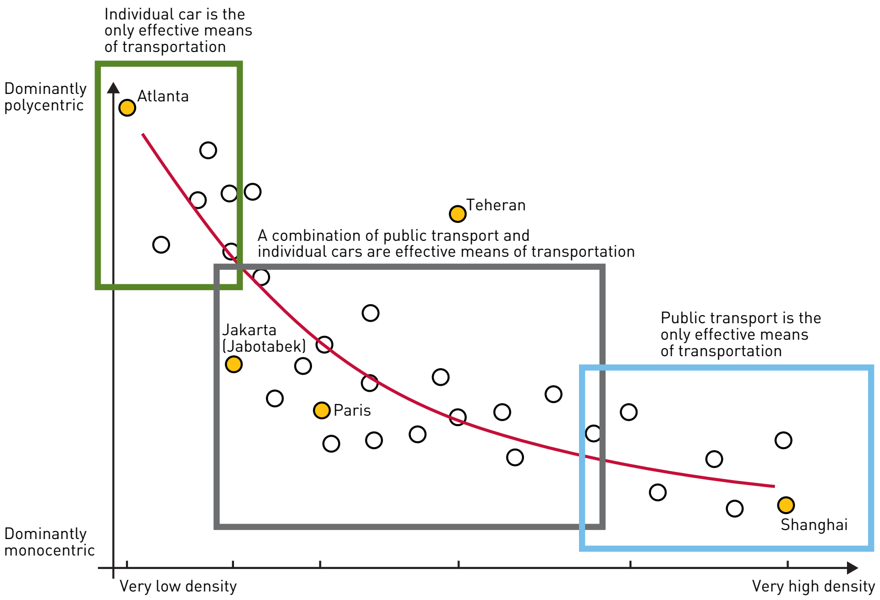

Figure 5. Relationship between Spatial Structure and the Effectiveness of Public Transport. Source: (Bertaud and Malpezzi, 2003).

1.5.3. THE "PUBLIC TRANSPORT CITY" OR "TRANSIT CITY"

The public transport city emerged with the arrival of the bicycle, the tramway and urban railways in industrialised countries between 1860 and 1940. Cities spread over 10 to 20 km and were star-shaped around public transport lines also set out in a star-like configuration. Population density diminished, between 5,000 and 10,000 inhabitants/km^2. Working and residential areas tended to settle around public transport lines. Centres of activity appeared when they were accessible from the city centre. The heart of the city was still very dense and composite and journeys were short. There were frequent pedestrian pockets of medium density around railway stations. Journeys were radial over long distances. (Newman, 1996).

Speedier travel began to be available to the poor when taxis and public transport appeared in the 17th century in Paris. In 1852, the world's first tramway line (animal drawn) came to New York. In the second half of the 19th century, efforts were made to replace horse-drawn systems and their numerous drawbacks with internal combustion engines. In 1863, the first steam-powered underground rail system appeared in London. After 1880, European cities installed electric tramways. The first of these in France was built in Clermont Ferrand in 1890.

This sketchy representation of a public transport city is particularly true of the time before automobiles were for sale. There were no cars at the end of the 19th century at a time when public transport was already being developed. Before the Second World War in Europe, the motorisation rate was of the order of 40 cars per 1,000 inhabitants.

1.5.4. THE AUTOMOBILE CITY

The automobile city emerged after the Second World War in developed countries when motorisation became general. The process was helped by massive investment in road infrastructure enabling spatial spread over a 50 km radius, with population density at about 1,000 to 2,000 inhabitants/km^2. This urban model is typical of the United States, Canada and Australia.

Activities are hardly mixed at all in the available space. Jobs are concentrated in the CBD and citizens live on the outskirts. Cars are the dominant means of transport and the intense segregation of activities in the available space does not allow for the use of slower conveyances. Public transport is marginalised and ends up being provided solely for the use of people who cannot drive or cannot afford to. The heart of the city is often entirely given over to a high density of commercial activities. Shops, services and industry are separate and scattered throughout the metropolitan area. Journeys cover long distances and are highly scattered (Newman, 1996).

1.5.5. THE BUS CITY

Barter (Barter, 1999) remarked that in the cities of the South, the various transport systems did not appear one after the other, as was the case in the cities of the North which had the opportunity of adapting to increased travel speed through gradual loss of density. When cars arrived on the scene, developed cities had been through the public transport phase so that there was already a certain degree of urban spread.

Barter points out that European cities in 1960 — at a time when population density was on average no greater than 10,000 inhabitants/km^2 and the motorisation rate was 100 vehicles per 1,000 people — had developed an effective public transport system, in particular railway systems with average speeds greater than those of buses. The cities of the South had not generally installed such railway systems. In the 1960s, their public transport systems were already based on buses and their motorisation rates were still negligible. Barter suggests the name "bus city" to describe them. Such cities have a high population density — greater than 15,000 inhabitants/km^2 — and buses are the main means of transport. The population density in these cities did not drop significantly when private cars began to overrun streets.

At this point, the cities of the South turned out to be much more vulnerable to the advent of the automobile than their northern counterparts. The steep growth in the number of cars inevitably leads to saturation of immature infrastructure. All the more so as the construction of new infrastructure is generally constrained by the weak financial and political capacity of the institutions in charge of urban development management. Barter replaces the notion of "automobile-dependent cities" (Newman, Kenworthy, 1999) by "traffic-saturated cities". In traffic jams, public transport is slower than private vehicles, so that only people who can buy a car or a motorcycle can increase their speed of travel. (Gakenheimer, 1997).

1.5.6. THE MOTORCYCLE CITY

Motorcycles play a growing role in mobility in cities of the South, particularly in South-East Asia. In Ho Chi Minh City in 1999, for instance, the motorcycle ownership rate was 300 per 1000 residents. In Bangalore today, two-wheelers are the majority of vehicles (74%) and are used for 31% of journeys; their annual growth rate has been on average 9.5% since 1991. In comparison, only two households in ten own a car and cars are used in 5% of journeys. With a motorcycle, the speed of travel is greatly increased for an initial outlay which is much smaller than for the purchase of a car. In an urban system, it has the advantage of taking up less space to park and in traffic than an automobile although it travels at about the same speed or even faster in a traffic jam. Motorcycles are therefore a logical choice when street space is limited. Barter therefore suggested the name "the motorcycle city" (Barter, 1999).

1.5.7. CONCLUSIONS

Accepting Zahavi's conjecture, Schaeffer and later, Barter, considered that the adoption of faster modes of transport has changed profoundly the spatial organisation of cities. The increase in average speed of a city's transport system calls for more space. The result is urban sprawl and reduced density. Dominant transport modes are therefore the determinants of urban structures. The increase in distance covered due to increased speed of travel and to urban sprawl leads to an increase in energy consumption as demonstrated by Newman and Kenworthy (Newman, Kenworthy, 1989).

2. DANGEROUS TRENDS IN TERMS OF GREENHOUSE EFFECTS

The following table provides some general elements of the "urban density/transport" evolution worldwide. Urban density is mostly regressing in the cities under examination, particularly in Western Europe (-20% in twenty years). Despite gains in the use of public transport (except in Australia), automobile use has grown significantly, mainly as a result of lengthened commuting distances from home to work.

These worrying trends are likely to continue. Furthermore, in view of the resilience and path dependency of urban structures, it is easier to reduce density than to increase it, as it is easier for a monocentric city to become polycentric than the contrary. There is also a global trend in the development of urban structures: on the one hand, cities grow larger as do CBDs. As they grow, the centres lose their compactness and therefore the proximity factor which was their main attraction. Inevitably, secondary centres will emerge so that the degree of monocentricity lessens as the size of the city increases. On the other hand, incomes and mobility increase in most megacities, densities diminish and, as a consequence, so does the role of public transport.

Obviously, these are not desirable trends in terms of environmental sustainability. But is not the pessimism of experts, who deem them to be inevitable, excessive?

Cities	American	Australian	European	Asian
Global urban densities (inhabitants+jobs / ha)				
1970	25	22	102	260
1990	23	18	82	235
Evolution 70-90	-8%	-18%	-20%	-10%
Home to work distance (Km)				
1980	13	12	8,1	
1990	15	12,6	10	
Evolution 80-90	+15%	+5%	+23%	
Automobile use (Km/yr/pers)				
1980	8,800	5,800	3,500	900
1990	10,900	6,500	4,500	1,500
Evolution 80-90	+24%	+12%	+29%	+67%
Use of public transport (PT trips/yr/person)				
1970	48	118	241	430
1990	63	92	318	496
Evolution 70-90	+31%	-22%	+32%	+15%
Modal PT share, 1990 average	2.8%	7.6%	22.3%	65%

Table 2. Evolution of urban density and the use of transport systems.
Source: (Newman and Kenworthy, 1999).

3. AN INEVITABLE FUTURE? NOT NECESSARILY: ATLANTA AND BARCELONA.

A comparison between two cities, Atlanta and Barcelona, whose demography and GDP per capital are similar, summarises the range of possible futures for the cities of the South (Figure 6). In Atlanta, the greatest distance between two points of the urban area is 137 km, as against 37 km in Barcelona. The small travel distances in Barcelona, due to the high density, enable its citizens to walk for 20% of their trips. In Atlanta, pedestrian travel is not even recorded. As a result, CO_2 emissions connected to urban transport are 11 times lower in Barcelona than in Atlanta.

But as we have noted, average density is not the only factor to influence travel distances. In a dominantly monocentric city, trips are generally shorter since they are mainly from the periphery to the CBD.

Dense, mixed, monocentric (so not over large since huge conurbations tend to become polycentric), highly structured through city planning and a transport system weighted in favour of public transport, supplemented by bicycles and walking, in a word, Barcelona (or Hong Kong) rather than Atlanta should be the overall model for cities of the South. Many of them already have these characteristics; so the issue is — fortunately — not so much how to increase density or reduce the use of cars, but rather how to preserve these beneficial urban structures. And yet, this does not seem to be the way we are going...

4. WHAT SHOULD BE DONE?

4.1. THE NEED FOR URBAN PLANNING INTEGRATING THE "TRANSPORT SUPPLY - LAND USE" RELATIONSHIPS

The demand for travel is a derived demand. The need to move is born of the need for individual exchanges within the city and the dispersion of areas of activity throughout the city. When the urban structure changes, so does the demand for travel.

Conversely, modifications in the transport supply lead to a multiplicity of changes: making choices regarding routes, sequence and mode of travel are all involved, but also destinations and the number of trips and even more fundamental decisions such as the purchase of a vehicle or the location of jobs, activities and housing. In the medium and long term, modifications of transport conditions entail a revision of certain choices of activity, such as where purchases are made and where to work and live. The urban structure itself is therefore also modified.

For example, the most significant benefit in the long term of a Mass Rapid Transit (MRT) system, bus or rail based, is probably that it concentrates urban development in accessibility corridors. It provides the necessary conditions to resist diffuse urban sprawl. But this possibility remains virtual unless MRT development is linked with appropriate land use and transport policies. In fact, construction of an MRT increases mobility leading generally, because of Zahavi's constant (see 1.5.1), to an increase in urban area. It is therefore necessary to complement the construction of an MRT with a land use policy, as we shall be discussing in section 4.

This pleads in favour of planning which explicitly integrates the effects of locating and relocating due to the siting of transport infrastructures; in other words, integrating the interaction between transport and land use. Since these interactions are extremely complex, one way of evaluating the impact of integrated transport and land use policies, is to use simulation models of urban dynamics, based on an in-depth understanding of the selection mechanisms for locations and transport. These are complex models and demand — as a minimum — a well documented geographic information system (GIS) of the city. For this reason, models are not yet much in use, but this is a field of research which should be prioritised so that townships can avail themselves of relatively simple simulation tools. They could then improve planning and interaction between the two major areas of public policy which can direct urban growth along sustainable paths: city planning and transport policy.

Although much remains to be done before the interaction between such policies is fully understood, it is possible, based on a large number of experiments, to draw up the main outlines of transport and land use policy combinations which are required to curb significantly current negative trends. They are summed up in Figure 7 which describes the "pincer movement" of complementary policies capable of controlling transport emissions in emerging cities.

4.2. TRANSPORT POLICIES

Progressing from the most superficial to the most deep-rooted urban transport-related emission determinants, i.e. from "end of pipe" technologies to action on the need for transport (via the structuring effects of transport infrastructure on the urban form itself), including action on modal choice, transport policies cover an array of practical measures ranging from improving vehicles to offering low-pollution, fast and comfortable public transport (so that even car owners may choose to use them), as well as inexpensive (so that the city can be accessible to the poor), including economic instruments with an impact on prices,

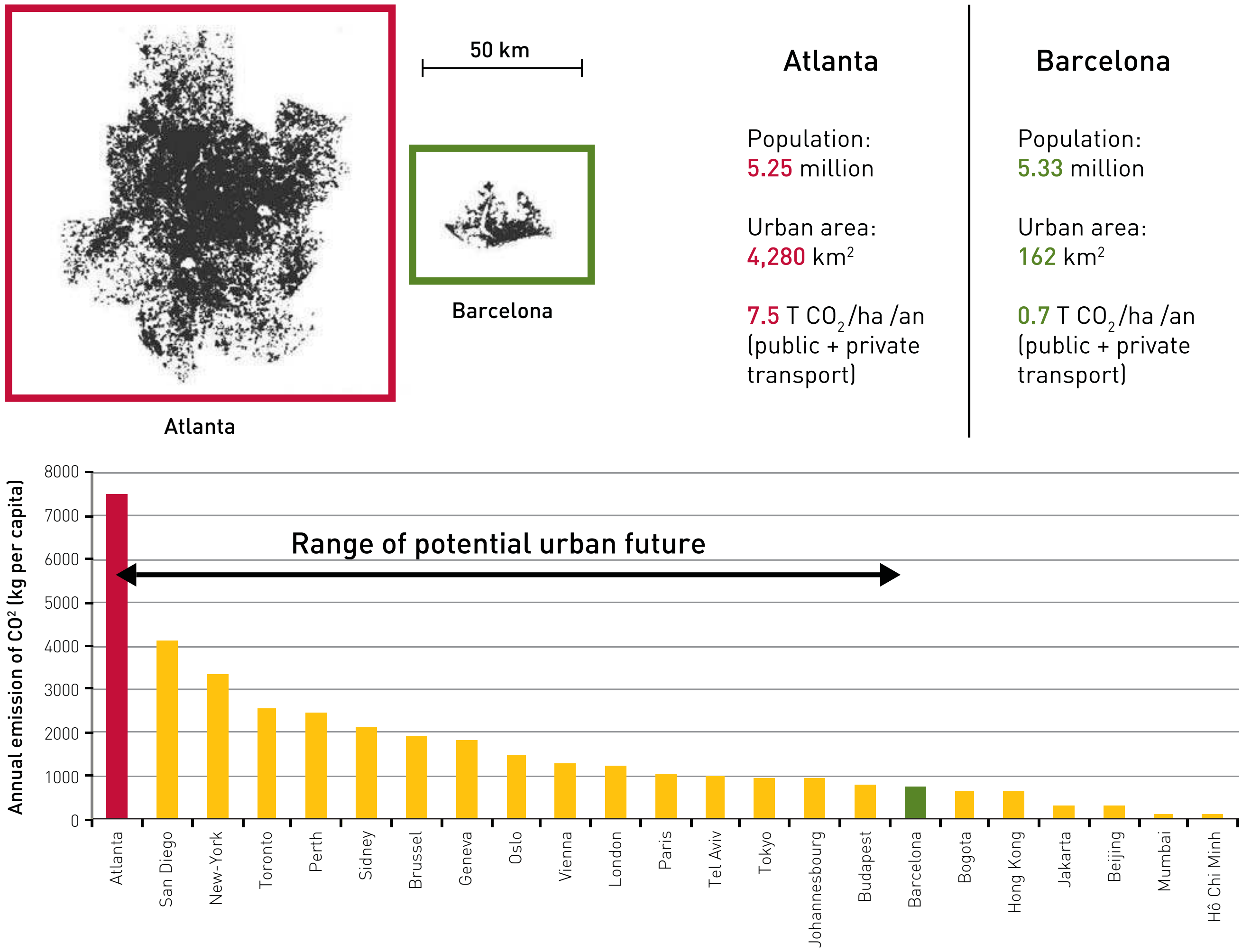

Figure 6. Atlanta or Barcelona, the range of possible urban futures. Source : Adapted from (Newman and Kenworthy, 1999).

generally aiming to support and complement other measures based on regulation and infrastructure improvements.

4.2.1. IMPROVING VEHICLES AND ECONOMIC INSTRUMENTS

The main measures that can be taken to improve the environmental efficiency of vehicles are the following:

- Improving the quality of road infrastructure which has a direct effect on the energy consumption per kilometre of the various types of road vehicles.
- Improving vehicle efficiency: reducing weight of cars, enhancing aerodynamics, improving engine performance; for motorcycles, promoting four-stroke engines.
- Improving fuel quality and introducing low-pollution fuels (natural gas, LPG, ethanol, methanol, etc.).
- Implementing environmental regulations: set programmes for vehicle inspection and maintenance and for the scrapping of obsolete vehicles.

These regulatory and technical measures may be supported and complemented by economic instruments based on the general principle of internalising, generally through taxation, the cost to the environment of the various modes of transport, to act as a deterrent against using the high-pollution varieties.[5]

Donors, the World Bank in particular, highly recommend such measures. They are of course advisable but they can lead to a significant increase in the cost of urban transport, for the poor in particular who are intensive users of highly polluting and dilapidated shared taxis, buses and rickshaws. Unless there is some alternative means of transport, cleaner but just as cheap, this kind of policy may be good for the environment but not so good for the poorer citizens, hence a dilemma. It does however turn out well in some cases, as exemplified by the relative success obtained in Delhi when buses and rickshaws transferred to gas.

However, the lack of control over modal distribution and more essentially over the need to travel is the reason why this kind of measure does not quite meet the challenge of urban dynamics in the cities of the South. In a study at the request of GTZ, Assmann and Sieber (2005) discuss these measures and demonstrate that, with a few exceptions, their efficiency in fighting greenhouse effects is limited, even when the price of oil is high. Mass Rapid Transit (MRT) must also be part of the supply.

4.2.2. THE PROMOTION OF MASS RAPID TRANSIT (MRT)

The urban structure of many cities in the South is, fortunately, still well suited to transport systems based on transit corridors. Urban development is often channelled by the major roads and not too scattered over the whole urban area. Even severely congested cities are more often car-saturated than morphologically dependent on cars, as yet. Contrary to car-dependent cities with highly scattered activities, in this context major passenger flows can be organised and it is therefore possible to develop Mass Rapid Transit systems.

MRTs generally operate at regular frequencies, along exclusive "right-of-way" lanes. MRTs have a greater capacity than traditional public transport (buses, vans, "busetas", shared taxis, etc.). MRTs are always provided with infrastructure to allow integration with other transport modes.

MRTs are generally classified into four different types: Heavy Rail metro; Commuter Rail (CR); light rail metro (Light Rail Transit, LRT); and the Bus Rapid Transit (BRT). Metro systems, heavy or light are still fairly rare in cities of the South, but there is currently general enthusiasm in favour of BRT technology, particularly since it was rediscovered successfully in the capital of Colombia, Bogota.

Heavy rail systems[6] are the costliest MRTs, but their theoretical capacity is the highest. Experience has shown that it is possible to cover the cost of operating heavy rail systems in high density urban areas, but they generally need large public subsidies. Because of its high cost, heavy rail does not meet the needs of rapidly expanding cities of the South[7].

Light Rail Transit[8] (LRT) is an electric metropolitan rail system operating with short trains using dedicated corridors, elevated, underground or street-level. LRTs generally include tramways, although these often run among other traffic without the benefit of exclusive corridors. Light Rail Transit seems more suitable for prosperous cities. Their capacity is equivalent to that of BRTs, but they seem to be on the wane in cities of the South.

Commuter Rail[9] or suburban rail is a system transporting passengers within an urban area or between a city and its suburbs. It differs from the two metro types because its carriages

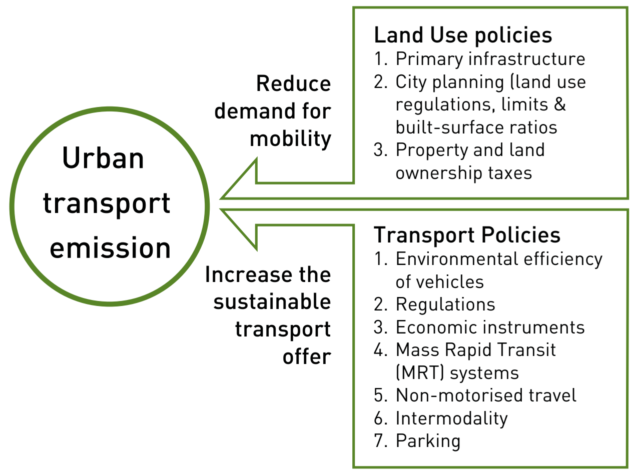

Figure 7. The urban passenger transport emission reducing policies"pincer"

[5] One example of taxation to discourage use of cars: the London "congestion tax".An example of a tax to encourage vehicle efficiency: differentiated tax stickers.
[6] In the South, Caracas, Bangkok and Mexico have heavy metro systems.
[7] In Mexico, the heavy rail network, with 11 lines covering 150 km, is only used for under 15% of motorised travel.The heavy rail in Buenos Aires, with 5 lines, is only used for 6% of motorised travel.
[8] LRT technology is to be found in particular in Kuala Lumpur and Tunis.
[9] In the South, Mumbai, Rio de Janeiro and Buenos Aires have commuter rail systems.

are heavier, it has longer routes and the tracks are generally part of an older rail system.

Many cities have developed variations on the theme of "improved bus service" and the Bus Rapid Transit (BRT) concept is more about a set of recommended practices than one single technique. BRTs operate using high technology buses along exclusive corridors, generally at street level. Their passenger boarding and discharging systems are fast. They use efficient ticketing methods at the entrance of comfortable stations, on-board technology for monitoring and managing operations, on-line passenger information systems and infrastructure for modal integration. BRTs are much more than a bus service operating along dedicated corridors: they are an integrated system, optimised to achieve transport quality and capacity very similar to that of rail systems.

In the case of poor cities, a significant impact on the modal distribution of travel is only in fact possible with bus-based MRTs, i.e. BRTs. Because of their high cost, the new metro systems can only be installed over a limited area and they have neither the same capacity as BRTs to satisfy all the demand, nor enough flexibility to be able to adapt to an expanding and fluctuating urban structure. The experience of Bogota and Curitiba show that BRTs were able to maintain, or even increase, the share of public transport versus cars.

The first reason for the current popularity of BRT technology is that it is low-cost. Its infrastructure is relatively lightweight so that the total cost of investment is reduced by as much as a factor of 100 compared to a heavy rail metro system. BRT stations in Quito, for instance, cost only US$35,000, whereas the light rail metro stations in Porto Alegre, serving a similar number of passengers, cost US$ 150 million. The total initial investment in the planning process, construction of infrastructure, technology and rolling stock required to develop a BRT system is in a bracket of US$1 to 10 million/km, whereas with a metro system, the range is US$ 55 to 220 million/km. As a consequence, for an equivalent investment, the BRT can serve up to 100 times the urban area covered by a metro. (Wright, Fjellstrom, 2003).

As regards operating costs, metro systems have in particular the advantage of reduced labour costs because only one driver is needed for a large number of railcars. But in poor countries, low salaries mean that other components far outweigh labour costs. In Porto Alegre (Brazil), both BRT and a heavy metro system operate in a similar context. With the rail system, 69% of operating costs per passenger has to be subsidized, whereas the BRT, which has a similar fare structure, operates without any subsidy and generates profit for its private operators (Thompson, 2001). Similarly, a USGAO study (2001) for the UN, compares six American cities with both a BRT and an LRT and it confirms that the operating costs of an LRT are about 1.6 to 7.8 times higher than those of a BRT.

Another point in favour of BRTs is that since their infrastructure is simpler, less time is needed for their construction. Bogota built its BRT in the space of 18 months. Elevated or underground metro systems, may take more than three years to build. This time element plays an important role in political terms: mayors can advance their political careers if a project is built during the span of one term of office and voters can enjoy its benefits before the next election.

A third point is that with a BRT, the flow of passengers served can be close to the numbers in a metro system (81,000 passengers/hr/line for high density metros as in Tokyo or Hong Kong, as compared to 33,000 for Bogota's BRT). An important factor, which determines the capacity of an MRT system, is the technology involved in procedures for passengers to board, alight and pay their fares.

A fourth point in favour of BRTs is that they offer a solution to the problem of conflict between fighting poverty and preserving the environment. BRTs provide quality service — which means that they are attractive to car owners for whom this point is critical — at an affordable price for the needy, without compromising the profitability of the whole operation. All of this being on offer over a large urban area, so that the less prosperous, living in the suburbs and very dependent on public transport, can still work in the city and enjoy the services it offers.

Environmentally speaking, all MRTs are an improvement insofar as they are a replacement for high pollution automobile and bus travel. Although in theory, the most energy-saving MRT is rail transport, load-factor is also a decisive factor. Furthermore, emission also obviously depends on the energy source used to produce electricity. In Bogota, the diesel fuel used for the BRT emits CO_2, whereas the Quito BRT uses hydroelectric power and does not.

4.2.3. NON-MOTORISED TRAVEL MUST NOT BE LEFT OUT

In most cities of the South, walking and cycling are still largely prominent in the modal distribution of travel. And yet, they are more often than not ignored in the city planning process. If "urban design" is not appropriate, if there is no separation from street traffic, or even no footpaths on which to walk, these non-motorised modes of travel are dangerous and tend to disappear, despite the fact that they represent a modest investment (US$25,000 to US$150,000/km for bicycle lanes), in particular compared to the vast amounts involved in "car-friendly" policies. For example, in Bogota, where bicycles were practically extinct, the local authorities built, in just a few years, 300 km of bicycle lanes, i.e. the largest network in the whole of Latin America. The modal share of bicycles grew from 0.4% to 3% of travel as whole, in that short time.

4.3. LAND USE POLICIES

4.3.1. STEERING A COURSE FOR MARKET FORCES

In the last few decades, most experts have gradually become convinced that market forces were so powerful as regards land use that it was not just very difficult, but also pointless, for authorities to oppose them head on. A consensus was therefore formed to the effect that traditional town planning, European style, based on detailed prior planning, massive public intervention in housing and special funding for construction, was gone for ever — "the fall of the Gods" (Haeringer and Goudiard, 2000). Because of general economic circumstances (re-definition of frontiers between States and markets) on the one hand, and on the other hand, very limited public financial resources — particularly in emerging countries, so that direct intervention in housing is a problem, with the price of real estate on the increase or even subject to speculative bubbles in many "global cities" — the "god-like" town planning era is giving way to "anticipation and support", of necessity more attentive to spontaneous forces.

To do so, the models with which urban majorities produce and reproduce their living spaces must be deciphered. Real estate and property markets, both formal and informal, send signals which are a reflection of urban structuring at work, and that regulators must integrate. The first task therefore is to gain a better understanding, in a particular city (since the local context is essential), of intensifying forces — concentrations and extensions, dilution of urban forms, the effects of improving accessibility using MRTs as they create new polarities, and altogether to understand the factors which determine where households and activities settle. In practical terms, public intervention is designed to complement the main thrust of urban production and, if possible, improve it.

The tools available to local authorities to influence the spatial development of their city are limited and, as a rule, are identical in the North and in the South. These tools can be classified into three categories: investing in primary infrastructure (roads, networks), regulating land use and property taxes.

4.3.2. PROPERTY RIGHTS AND LAND REGISTERS

Regulations and taxes must be based on some kind of land and property register, or at the very least some equivalent source of information. This is where the situation is very different North and South. Setting up a land register immediately raises the difficult problem of defining and allocating property rights on land and real estate. In most countries of the South, such rights are very complex. Both traditional and imported systems are in use side by side, together with a wide variety of implementations and interpretations of the theoretical simplicity of Roman Law or even of Common Law. Naturally, in such cities, there are many examples of occupation and construction with neither traditional nor modern legal justification of any kind, in particular on publicly-owned land.

It is all very well to state, as do a great number of development agency experts, that the priority in cities of the South is to define property rights and allocate them to public or private owners, so that land and property markets can function properly and the authorities can act through regulations and taxes. This is certainly true in theory. But in order to do so, land registers must be drawn up and rights defined. In practice however, according to Vincent Renard, land registers and legal systems for the implementation of urban property rights which were gradually put together over many years in rich cities and now proposed as a model by consultants in the cities of the South, are so sophisticated that setting up land registers would take more time than is available before the completion of the current rapid urban expansion phase (Renard 2002). As Joseph Comby also emphasises, creating a sophisticated land register can inhibit property development (Comby, 2000). As regards the legalisation and registering of property ownership, much simpler solutions must be chosen, even at the price of some approximation which can be sorted out later.

These criticisms did not go entirely unheeded. For example, the simple "addressing" technique has been developed in a number of countries, in particular in World Bank programmes. Addressing consists in drawing up a register of urban population which starts very simply since the "root information" is just the address. Later, as needed and depending on data collection capacities, a wide variety of data the authorities might require to formulate and implement their urban policies, can be added gradually, such as type of street or of building, surface area, water meter numbers, etc.).

4.3.3. PRIMARY INFRASTRUCTURE INVESTMENTS

These investments obviously have an influence on spatial structure. As a rule, private land use development can only take place at a distance of about one or two kilometres from primary infrastructure, sometimes much less where topography is difficult (Bangkok, for instance). The lack of infrastructure tends therefore to have the effect of dispersing built-up areas along regional radial communication lines.

As a result, in the context of city centre reinforcement (monocentric development), the authorities must take care to ensure that primary infrastructure serves all the urban areas which are closest to the city centre as a priority. Linear urbanisation along the major radial axes, a "stellar" development of the city, lengthens travel time and distance while it also fragments the labour market for the poorer households. These outward linear developments are caused by insufficient primary infrastructure in the areas situated between the radial routes and closest to the centre.

4.3.4. LAND USE REGULATIONS

Such regulations set out the use of land, using methods which range from simple zoning to detailed land use planning policies strictly governing where construction is allowable and the built-surface ratio.

Today, there is a consensus that in a number of countries, excessive and hypertrophic regulations with their cascade of consequences in terms of delays, costs and legal uncertainty, hinder construction productivity. The accumulation, complexity and sometimes doubtful consistency of all these rules can be an obstacle in the way of controlled development of urban areas since they generate strategies for circumventing the rules and the climate of uncertainty they themselves helped to create. Simplification and clarification are essential requirements on which everyone can agree and they are of essential importance. However, underlying this consensus that simplification and clarification are essential, there is keen disagreement on the need for and the method of regulating land use.

Those in favour of deregulation consider that land use rules are often the main cause of spatial dispersion, which may seem paradoxical since dispersion is never the explicit objective of regulation. However, the reasoning is simple: regulations always stipulate minimum sizes for plots and maximum density and built-surface ratios; never the other way around. As a result, regulations compel families to use up more ground space than they would otherwise choose to do if they had a choice. Poor families can only access property ownership if they use up less land than the middle classes. Being forced into using a minimum of land — the result of regulating the size of plots and the built-surface ratio — pushes the poor towards the city outskirts where the price of land is compatible with regulated built-surface density, or to more central, but space-limited, unregulated shantytowns. Similarly, as regards wealthier segments of the population, price increases for real estate in the city centre reinforce their preference for living in the outskirts where the price of land is lower so that transport time and distance can be offset by having a larger house. These converging trends increase the need for mobility. Urban dispersion can therefore be explained by the rise in real estate prices due to the scarcity of supply, which is itself a consequence of the rules restricting the right to build.

So as to limit the boom in real estate prices and uncontrolled urban sprawl, "real estate" (private) strategies based on deregulation have been tried out in various countries. V. Renard considers that these policies repeatedly turned out to be disappointing, or even decidedly counter-productive (Renard 2002).

In particular, land deregulation in the suburbs does not seem to be a useful tool in the fight against the takeover of land that should not be urbanized or against uncontrolled urban sprawl. In the outskirts, after a number of experiments, it must be recognised that deregulation pure and simple with the aim of lowering prices and helping the poor to gain access to the housing market, not only does not work but may also turn out to be very ineffective due to the dispersion it can cause, with as a consequence: costlier basic urban services (roads, water, drains, electricity) and increased dependence on private transport. It would seem preferable to organise "real estate production" operations, which literally "prepare the ground" (for private urbanisation). This involves public agencies, or private operators under contract, who anticipate urban extension and channel it with an offer for minimum basic infrastructure (according to Michel Arnaud, the minimum required is to mark out the footprint of future roads and drainage and only later go on to connecting networks).

It does seem clear, however, that specifying a minimum size of plot and maximum built-surface ratios and density can prove an obstacle to intensification and diversification of land use in city centres. In areas where accessibility is excellent, modifying these rules (maximum plot size, minimum built-surface ratio and density) and adapting land use plans to facilitate a functional mix would make it possible to concentrate private investment initiatives and therefore the origins and destinations of daily commutes. One special case, of some importance in certain cities (Casablanca and most South Asia cities, for example), is where shantytowns are embedded at the heart of a city. Razing them to the ground and rehousing their inhabitants in outlying districts was for a long time, and frequently still is, the only official policy. In the meantime, building publicly owned dwellings to rehouse the former shantytown inhabitants is never sufficient (privately built housing being obviously too expensive or too far from the city for them, otherwise people would not be living in shantytowns in the first place) and residents refuse to be exiled in remote areas, (often without public transport), so that the shantytowns can never be totally eliminated and are constantly reborn. In some countries, Morocco for instance quite recently, the authorities are considering restructuring shantytowns, with most of their present inhabitants staying on. But this always requires that the standards which are supposed to apply in "formal" housing be re-defined (minimum plots, built-surfaces and housing standards).

4.3.5. PROPERTY TAX

Taxation may have an indirect, but significant, effect on urban spatial structure in that it modifies the quantity of land used and encourages or paralyses transactions. If the object is urban structuring, the tax must be able (through tax base and rate) to adapt to market developments, which requires that land and real estate transactions be monitored and therefore given some degree of visibility. Furthermore, it will be necessary to harmonise the views of the various branches of government — those in charge of the economy and those responsible for infrastructure. The Treasury will be justifiably concerned with tax yields and management costs, while the government departments in charge of community facilities and amenities will be more inclined to concern themselves with the specific incitements that taxes can generate, such as contributing to an increase in the supply of housing or encouraging this or the other use of urban area.

A good illustration of a property tax designed primarily to produce substantial resources exists in the United States: the property tax, based on the market value of real estate, produces almost 70% of the tax receipts of local authorities. However, the tax burden and the tax base which are regularly reappraised can serve as an incentive by adjusting these parameters, possibly contractually. In this way, such incentive taxation, if it is adequately combined with spatial planning and controlled zoning, can help maintain agricultural or natural resource conservation areas in the outlying belts of cities threatened by urbanisation. Another example is to be found in Denmark where, also backed up by constantly updated assessments of market value, a sophisticated property tax system is able to neutralise the impact of city planning rules on the price of real estate, in particular through heavy taxation of operations aiming to build on agricultural land.

Theoretically, but also practically, in certain rich cities, we find therefore that a property tax system can usefully support and complement regulatory policies on city density and mix, concentration of origins and destinations of daily commutes and control of urban sprawl. Naturally, in cities of the South, because of the absence and inaccuracy of land use registries or of whatever is used in their stead, as we mentioned above, because of the frequent presence of an informal ownership market for which prices are largely unknown[10], using property taxes as an incentive is rather more difficult and it would be a mistake to recommend such a policy unless the conditions for it to be effective are present.

There is some progress however in another direction: the various methods used to obtain a financial contribution from owners whose properties become more valuable as a result of public construction works, such as sewage collection systems, surfaced roads with sidewalks or MRTs.

In conclusion, we should emphasise that land use policies, just like transport policies, are simply a means to attain more general objectives. If clear and stable objectives can be formulated for the kind of "city we want", then such policies should be consistent. In practice, however, we do find that city planning and transport planning are, more often than not, developed independently without regard for possible interactions and even without any clearly defined common objective.

5. CONCLUSIONS

Exponential urban expansion in countries of the South is, without doubt, one of the major environmental challenges of this century. Current trends in urban developments are a reason for concern in terms of climate change, because they are allowing private cars to gain predominance over public transport or non-motorised travel. This is true of both North and South, but the crucial challenge is in the South: will the cities of the South follow the lead of Atlanta or Barcelona? Brisbane or Hong Kong?

To simplify, there are four possible urban structures the cities of the South can choose from: a sprawling polycentric city (Atlanta), a dense monocentric city (Barcelona), a city made up of a relatively dense centre surrounded by satellites and a dual city made up of a modern international standard type centre more or less loosely connected to a traditional city. The first question local authorities must ask and respond to is: "what kind of city do we want?". Since environmental constraints impose a limitation on expanding the use of cars, even if they were to become more environmentally-friendly, the first alternative, i.e. the sprawling city, is to be avoided.

For the three other types of structure, constructing an energy-sustainable urban future is not, theoretically, an impossible task. To achieve this, urban energy consumption needs to be squeezed between transport and land use policies: make motorised vehicles less polluting, discourage the use of private vehicles, promote efficient public transport systems, specially BRTs, adjust urban planning laws as well as land use and built-surface regulations to help concentrate private investment in highly accessible areas generated by the construction of an MRT, to reduce mobility requirements thanks to greater density and function mix, and to encourage non-motorised travel by appropriate urban design and meshing together of the various modes of transport.

All of this is within the grasp of the major cities in the South, some of which are justifiably proud of spectacular successes. But these successes are only rarely, if ever, born of the will to reduce greenhouse gas emissions. This was not the reason why the mayor of Bogota presided over the construction of an efficient BRT network; the object was to improve the everyday life of his constituents so as to be re-elected and further his political career.

We consider that, at this point, the core problem is incentive. Since the protection of a global public good — the climate — is in question, then urban policies should qualify for incentive measures and CDM type transfers provided for in the Kyoto Protocol. But this is not the case, *inter alia* for practical reasons: it is very difficult to prove that transport and land use policies, whose objectives are obviously multiple, satisfy the additionality constraint. To state this in less technical terms, when an urban policy succeeds in reducing pollutant emission, it is very difficult to separate emission reduction which is simply a favourable consequence of an urban policy in pursuit of other objectives — this being in itself, amply justified on a local basis — from additional reductions connected to a specific effort to combat greenhouse effects conferring the right to participate in an emission allowance trading scheme, in whatever form.

But when a electricity generating company in the South improves the efficiency of a power plant, its investment can be funded by another actor working under an emission constraint. Why should this not be allowed for a mayor who manages to improve the energy efficiency of his city? We are convinced that there is a real need for mechanisms which could provide better incentives for local authorities in the South to forge ahead in the direction of energy efficiency.

And clearly, as is the case on all the greenhouse gas emission reduction fronts, it is up to the cities of the North to lead the way and it is the countries of the North who must encourage massive transfer of the best technologies.

[10] Although it is true that, thanks to a number of sociological and economic surveys, the property markets in shantytowns and the economic practices of their residents, for example, are now fairly well known.

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